

## Equilibrium Studies on Some Lanthanide(III) Complexes with Oxine as Primary Ligand and Vitamin U as Secondary Ligand and Its Comparison with Binary Complexes

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The formation constants of the mixed ligand complexes at 1 : 1 : 1 optimum molar concentration of metals such as La(III), Pr(III), Sm(III) and Gd(III) as primary ligand, A = oxine and N—O donor atoms as secondary ligand, L = vitamin U have been determined by modified form of Irving-Rossotti titration technique in aqueous media at constant ionic strength ( $\mu = 0.2 \text{ M dm}^{-3}$ ) at  $25 \pm 0.1^\circ\text{C}$ . The difference between the stability of ternary complexes and the corresponding binary complexes has been expressed in terms of parameter  $\Delta \log K_T$ . The stabilities of the ternary complexes are explained in terms of  $\pi$ -basicities, structures of secondary ligand and ring size of chelate.  $\Delta \log K_T$  values are negative which suggest favourable formation of ternary complexes. The  $\Delta \log K_T$  values have been explained in terms of  $M \rightarrow L$ ,  $\pi$ -interaction, size of the chelate ring and factors from metal side.

**Key Words:** Stability constants, Potentiometric studies, Lanthanide ions, Ternary complexes.

### INTRODUCTION

The ligand, vitamin U (methyl methionine sulfonium chloride, MMSC) is an  $\alpha$ -amino acid. This compound, containing both active  $-\text{NH}_2$  group and an acidic group  $-\text{COOH}$ , has a wide variety of applications in medicine, biology and other fields of chemistry. In recent years, considerable interest has been shown on the synthesis of metal chelates of catalytic and physiological importance, containing nitrogen and oxygen donor atom<sup>1</sup>. Vitamin U has protective effect against ethanol-induced injury in rats and the antiulcer effect of vitamin U is related to its gastric mucin-increasing action<sup>2</sup>. A previous study<sup>3</sup> showed that L-cysteine and vitamin U inhibited ethanol-induced gastric mucosal damage and increased the amount of surface mucin in rats. Vitamin U is also used in antiradiation effects<sup>4</sup>. Cytoprotective effect of vitamin U on necrotizing agent-induced gastric

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mucosal damage in rats has been carried out<sup>5</sup>. Akbarov *et al.*<sup>6</sup> demonstrated that the main factor in activation of Ca-dependent ATPase is by cobalt complexes with vitamin U, glycine,  $\alpha$ -alanine etc. Invention provides a therapeutic composition for use in the treatment of mucosities and method for using such a therapeutic composition<sup>7</sup>. Experiments were made on the investigation of the effect of vitamin U and nickel complex on the process of lipid peroxidation in rat liver<sup>8</sup>. Thermolysis study of vitamin U with some of its nickel(II) complexes has been carried out<sup>9</sup>. Oxine is found to be a potential chelating agent and important physiological activities, *e.g.*, antimalarial.

Scientists have focussed considerable attention on lanthanides and their coordination compounds. This may be considered a leading branch in different areas of chemistry in future.

### EXPERIMENTAL

Oxine and vitamin U (Fluka), sodium perchlorate (Fluka), perchloric acid (BDH) were used. Stock solutions of La(III), Pr(III), Sm(III) and Gd(III) perchlorate solutions were standardized by complexometric EDTA titrations<sup>10</sup>. Carbonate-free NaOH solution was standardized by reported method<sup>11</sup>.

Conductivity water is used throughout the experimental work. Digital  $\mu$ -361 pH-meter with readability  $\pm 0.01$  with combined glass calomel electrode has been used for potentiometry. Stoichiometrically 1 : 1 : 1 concentration of Lanthanoid(III), A and L is maintained in the solution. Five sets of the solutions were prepared containing (1) known amount of free HClO<sub>4</sub>, (2) free HClO<sub>4</sub> + known amount of primary ligand, (3) free HClO<sub>4</sub> + known amount of secondary ligand, (4) free HClO<sub>4</sub> + known amount of primary ligand + known amount of metal perchlorate, (5) free HClO<sub>4</sub> + known amount of primary ligand + known amount of secondary ligand + known amount of metal perchlorate.

Total volume of each mixture was raised to 50 mL using conductivity water.

$$\Delta \log K_T = \log K_{MAL}^{MA} - \log K_{ML}^M$$

where

A = oxine; L = vitamin U

### RESULTS AND DISCUSSION

From titration data given in Fig. 1,  $\bar{n}H$ ,  $\bar{n}$ , pL,  $pL - \log \left( \frac{1 - \bar{n}}{\bar{n}} \right)$  were calculated on the basis of literature method<sup>12, 13</sup> and binary and ternary formation constants are presented in Table-1.

The stability constants of the ternary complexes can be determined using two approaches:

1. Formation of mixed ligand complexes [MAL] takes place in two steps.

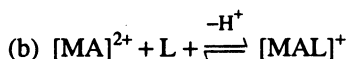
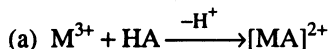


TABLE-1  
PROTON LIGAND AND MIXED LIGAND FORMATION  
CONSTANTS OF LANTHANIDE(III)-HETEROCHELATES  
AT TEMPERATURE  $25 \pm 0.1^\circ\text{C}$ ,  $\mu = 0.2 \text{ M}$  ( $\text{NaClO}_4$ )

Ligand $\text{pK}^{\text{H}}$ values	Metal-ligand formation constants							
	La(III)		Pr(III)		Sm(III)		Gd(III)	
Vitamin U	$\log K_{\text{La.L}}^{\text{La*}}$	$\log K_{\text{La.A.L}}^{\text{La.A}}$	$\log K_{\text{Pr.L}}^{\text{Pr*}}$	$\log K_{\text{Pr.A.L}}^{\text{Pr.A}}$	$\log K_{\text{Sm.L}}^{\text{Sm*}}$	$\log K_{\text{Sm.A.L}}^{\text{Sm.A}}$	$\log K_{\text{Gd.L}}^{\text{Gd*}}$	$\log K_{\text{Gd.A.L}}^{\text{Gd.A}}$
$\text{pK}_1^{\text{H}} = 8.25$	9.68	5.62	9.85	5.67	10.19	5.72	9.85	5.78
$\text{pK}_2^{\text{H}} = 2.17$								
$\Delta \log K_{\text{T}}$	-4.06		-4.18		-4.47		-4.07	

\*Values are taken from literature.

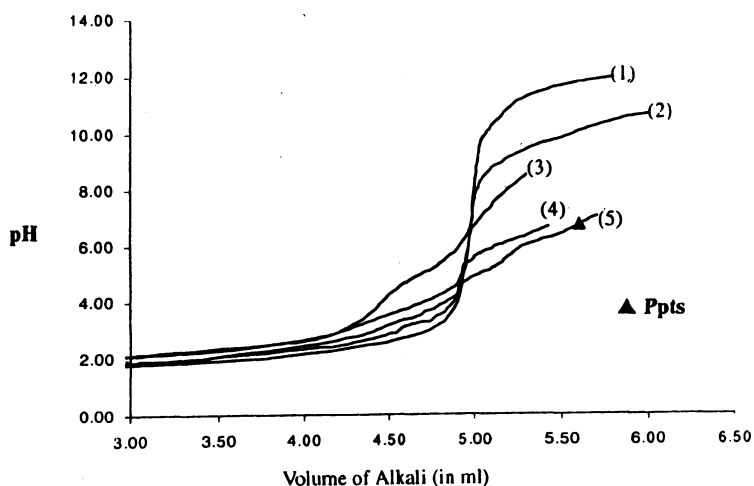
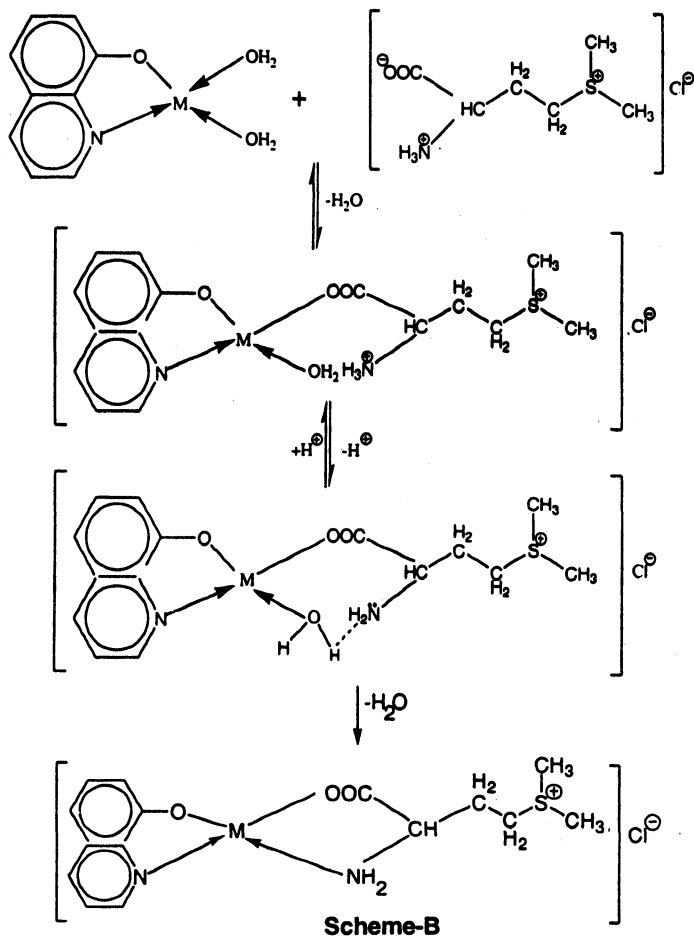
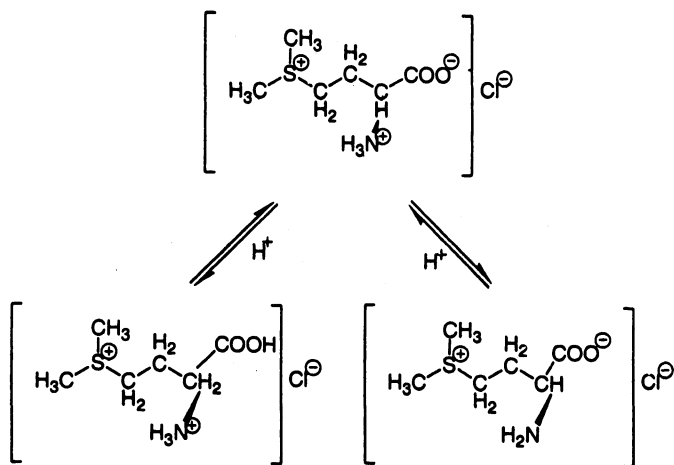


Fig. 1. Pr(III)-Oxine-Vitamin U system temperature  $25 \pm 0.1^\circ\text{C}$ . (1) Acid, (2) Oxine, (3) Vitamin U, (4) 1 : 1 molar ratio of Pr(III)-oxine, (5) 1 : 1 : 1 molar ratio of Pr(III)-oxine-vitamin U.

2. Simultaneous reaction between the metal ion and two ligands resulting in the existence of various species<sup>14</sup> namely  $\text{AH}$ ,  $\text{A}^-$ ,  $\text{LH}_2^+$ ,  $\text{LH}$ ,  $\text{L}^-$ ,  $[\text{MAL}_2]$ ,  $[\text{MAL}]^+$ ,  $\text{M}^{3+}$ ,  $[\text{MA}]^{2+}$ ,  $[\text{ML}]^+$ ,  $[\text{MA}_2]^{2+}$  and  $[\text{ML}_2]$ .

The protonation of vitamin U is expected to take place as shown in **Scheme-A**. Formation of  $[\text{M(III)-oxine-vitamin U}]$  chelate is shown in **Scheme-B**.

The mixed ligand formation of 1 : 1 : 1 ternary complexes of  $\text{M(III)}$  were calculated by considering that 1 : 1  $[\text{M(III)A}]^{2+}$  complex is completely formed and then after the coordination of the secondary ligand  $\text{L}$  takes place. From statistical consideration also the driving force for binding secondary ligand with  $[\text{MA}]^{2+}$  should be less than for binding  $\text{L}$  with  $[\text{M(aq)}^{2+}]$ . Electronegativity of  $[\text{M(aq)}_n]^{2+}$  and  $[\text{M(A)}]^{2+}$  is approximately almost same. The 1 : 1  $[\text{M(III)A}]^{2+}$  is stable up to *ca.* 5.5 pH.  $[\text{MA}]^{2+}$  complexes are formed at lower pH and are stable



at higher pH where mixed ligand formation takes place. In the presence of secondary ligand, hydrolysis of  $[MA]^{2+}$  is suppressed; therefore, there is formation of mixed ligand complex, MAL, at higher pH. Studies on ternary complexes have revealed<sup>15-17</sup> that presence of aromatic nitrogen donating ring becomes more selective and discriminating towards incoming secondary ligand. The  $\log K_{MAL}^{MA}$  observed formation constant values indicate similar nature of oxine, ternary complexes.

Lanthanide contraction occurs due to poor shielding of 4f electrons and a steady increase in effective nuclear charge is observed. This phenomenon is best represented by the radii of tripositive ions.  $Gd^{3+}$  however shows a discontinuity due to spherical symmetry (4f<sup>7</sup>). In the presence of water, complexes with nitrogen, sulphur and halogen (except F) donor ligands are not stable. The 4f electrons are buried so deeply (compared to 5f) within the atom that they are unaffected by the environment to any great extent. The value of ligand field stabilization energy (LFSE) is minimum due to absence of significant interaction with 4f orbitals. The lack of significant LFSE reduces overall stability and simultaneously provides greater flexibility in geometry and coordination number. Transformation of one into other geometry and coordination number is relatively easy as there is no loss of LFSE. The degree of hydration of lanthanide ions  $[M(H_2O)_9]^{3+}$  is a subject of long debate. As we move from  $La^{3+}$  to  $Sm^{3+}$  the ionic size decreases and partial molal volume decreases until crowding of ligands becomes intense. At  $Sm^{3+}$  one water molecule has to leave. The decrease in size affects the coordination number of the metal ion. Due to this, there is a decrease in coordination number. When other factors are same, the increase in acidity due to decrease in size facilitates better coordination. Stability of lanthanide complexes are increased by means of chelate effect. The results of the stability of lanthanide complexes are only partially interpretable in terms of simple models. Simple electrostatic or acid-base concept of size and charge is not successful in characterization of the stability behaviour of lanthanide complexes, and all lanthanides show discrepancies from the simple picture and often show no change or even decrease in stability with increase in atomic number. Except  $Gd^{3+}$  and  $La^{3+}$ , partially filled f-orbitals provide small LFSE which partially explains the discrepancy. This is the reason for the fall in stability of  $Gd^{3+}$  complexes, and it is known as gadolinium break<sup>18</sup>. The  $K_{MAL}^{MA}$  values are lower than the  $K_{ML}^M$  values which are in the order of La-Oxine-Vitamin U < Pr-Oxine-Vitamin U < Sm-Oxine-vitamin U < Gd-Oxine-Vitamin U as expected with respect to electronic configuration, size, Paulings's electronegativity, ionic potential of trivalent metal ions, nature of the concerned ligands and stereochemistry of the complex.

Vitamin U has  $\alpha$ -amino acid moiety which usually has good chelating property, in which the basicity of nitrogen of  $\alpha$ -amino acid moiety is reduced due to carboxyl group attached to nitrogen. The values originate from back donating tendency of primary ligand, besides  $N \rightarrow M \sigma$ -bonding there exists strong  $M \rightarrow N \pi$ -interaction; as a result the concentration of charge on the metal ion does not take place. The  $K_{MAL}^{MA}$  values in case of oxine are neutral in character and contain heteroatoms in the aromatic rings. The stability of oxine complexes can be explained on the basis of the fact that oxine has one extra fused benzene

ring attached to the heterocyclic ring and the distribution of electron charge cloud is expected to be maximum<sup>19</sup>.

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